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Models and Modelling in Archaeology

Oliver Nakoinz [*]

Abstract: *»Modelle und Modellierung in der Archäologie«*. Being a discipline in-between natural science and humanities, archaeology has conflicting attitudes towards models. On the one hand the term model is currently very fashionable, while on the other hand there is a certain ignorance and even rejection of models in archaeology. This is caused by limited knowledge on models, the polarization of assumed paradigms, and different developments in different subcommunities in archaeology. Models in archaeology range from conceptual social models over typo-chronological models, regression models, network models and 3d models to simulations. One single definition of models seemingly does not work in archaeology, whereas a structured set of different terms based on an overarching definition of models would make sense. Since most models in archaeology are derived from other disciplines, the field would benefit from a trans-disciplinary modelling framework to enable efficient knowledge transfer. In order to establish a fruitful application of diverse modelling frameworks in archaeology, the establishment of disciplinary modelling communities together with a trans-disciplinary modelling community, as well as a proper education in modelling concepts and techniques, is required.

Keywords: Modelling, model, archaeology, theory, method, simulation.

1. Introduction

1.1 About Fashions

"This is just a model!" is a frequently heard statement in archaeology. It indicates a rather negative attitude towards models. Models are something of low quality, are rather hypothetical than being proper knowledge, and are inaccurate, positivistic, and at best a nice visualization.

On the other hand, "model" and "modelling" are fashionable terms in archaeology. Graphs of the key word "model" used in combination with a number of disciplines in the catalogue of the Library of Congress in Washington visualises the increasing popularity of the term (Fig. 1). While models became fashionable in mathematics in the late 1950s, caused by the introduction of digital computers and Tarski's English publications on models, it took another

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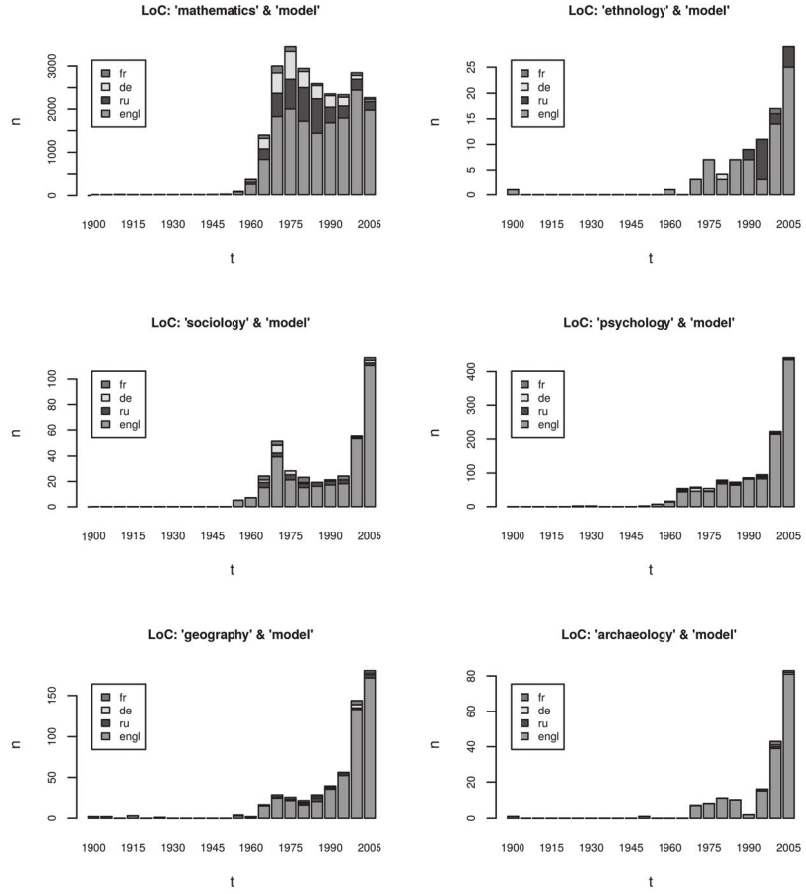
decade for the trend to keep up in other disciplines. In archaeology, geography, sociology and ethnology a first modelling hype took place in the late 1960s and early 1970s, followed by a phase of avoidance of the term "model" in the 1990s. In the late 1990s a second modelling hype started, which is still ongoing. Today modelling is at the same time very fashionable and much criticised.

The trendiness of a term does not say anything about the actual importance and usage of a certain concept but rather reveals something of the driving social processes of science.

Figure 1: Frequencies of the Key Word "Model" Occurring in Combination with the Name of a Discipline in the Catalogue of the Library of Congress in Washington



Source: Nakoinz and Knitter 2016, fig. 1.1.

1.2 About Paradigms

In the 1960s and 1970s archaeology was attracted by concepts adopted in natural sciences, which influenced the development of the so called "New Archaeology", a flavour of archaeology which stresses approaches in the natural sciences, quantitative methods, objectivity, mathematical concepts, structures and functions, modelling, and anthropological analogies. New Archaeology aimed to replace the cultural historical paradigm and was itself replaced by "Postprocessual Archaeology", a postmodern flavour of archaeology. Postprocessual archaeology focused on meaning, subjectivity, interpretation, individual decisions, semiotics and theory. New Archaeology and Postprocessual Archaeology have been some of the responses to a general development, to which the rise, the decline and the revival of modelling in archaeology are also due. There is no paradigm succeeding the post-processual paradigm. "Officially" we are still in the postprocessual period, but the word counts of "model" reveal that the "ideological power" of this paradigm has decreased and perhaps, unnoticed, reached the status of an integrational paradigm.

Before we are able to assess any paradigm, we need to discuss the role of archaeology as a discipline in-between natural sciences and humanities. It is obvious that archaeology is one of those disciplines in-between natural sciences, social sciences and humanities, such as geography and sociology. In particular, it seems that archaeology is alternating between the two extremes of the natural sciences and the humanities. But what exactly is the problem of the divide between science and the humanities? According to Snow (1960) the two communities are just not able to communicate. This is certainly a serious problem, but not the main problem for archaeology. The main difference between science and the humanities is that science follows an approach to knowledge which defines meaning based on structures observed in nature, while the humanities follow an approach to knowledge which negotiates pre-existing meaning. Archaeology starts with the humanities. We know something about human beings and ask questions about historical events and social structures. Our data derived from archaeological finds do not have meaning attached to them, they just have assumed meaning. However, in archaeology there is the need to switch to concepts of the natural sciences. We use the natural sciences as the source of specific data such as environmental data, but the crucial point is that we need to analyse the structure of the archaeological data with scientific concepts in order to reveal the meaning of the objects. At the end of this analytical process archaeology can switch back and answer the historical questions.

1.3 About Integration

This description shows that for archaeology to alternate between the humanities and science in the evolution of the discipline rather than within specific research projects is rather problematic. Only half of the research agenda of ar-

chaeology can be completed by adopting exclusively one of the two approaches.

Both "paradigms", New Archaeology and Postprocessual Archaeology, propagated paradigm shifts *sensu* Kuhn (1962). These paradigms do not correspond exactly to a scientific or a humanities approach, but there is a certain correlation. While New Archaeology tends to ignore the need of the humanities, Postprocessual Archaeology tends to ignore scientific methods.

There are at least two levels of complementarity, the one concerning scientific and humanities approaches, and the one related to preferred topics of New Archaeology and Postprocessual Archaeology. This complementarity clearly shows that the idea of paradigm shifts is rather absurd in this case, since they are not incommensurable "paradigms". Since the publication of Kuhn's book (1962), paradigm shifts have become tools for stimulating a researcher's career. The conjuncture of models in archaeology has to be seen in relation to this social and historical background. The arguments and discussions on models are hence partly based on the actual content being discussed and partly on ideology in connection to certain assumed paradigms.

2. Different Types of Models and Terms in Archaeology

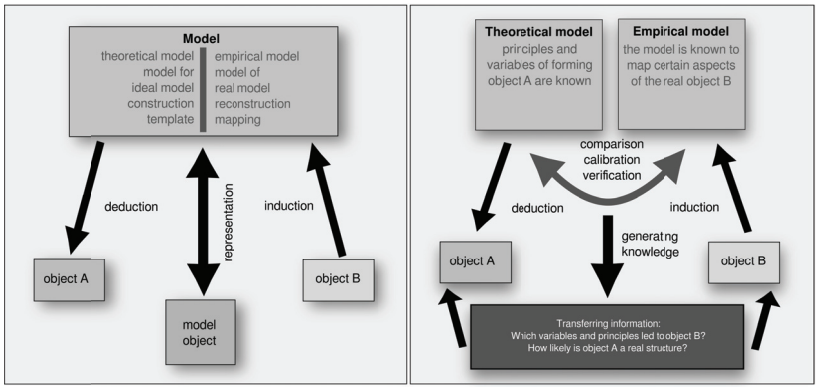
In addition to the confusion based on the "war of paradigms" mentioned above, archaeology features a rather wide range of different kinds of models. Due to the fact that archaeology needs to borrow methods and concepts from other disciplines, the variation of models in archaeology matches the number of disciplines it borrows from. For most types of models rather small communities exist which deal with these models. A lot of work is invested in working implicitly or explicitly with models, but although the term model is fashionable, it is generally assumed that modelling does not yet play a central role in archaeology as a whole. A modelling community covering models in general does not yet exist, while communities working on predictive modelling or network modelling are quite active. Below we will explore different types and terms of models.

One of the first explicit contributions to a kind of archaeological theory of models is David L. Clarke's article "Models and paradigms in contemporary archaeology" in his edited volume "Models in Archaeology" (Clarke 1972). He characterises a model by four terms: comprehensiveness, predictiveness, efficiency and accuracy. This makes it clear that he had a certain type of model in mind concerned with prediction. Considering that his friend Peter Haggett co-edited a volume on models in geography (Chorley and Haggett 1967) and was deeply involved in locational theory, this is not surprising. This friendship is responsible for most of the archaeological understanding of models during the following decades. The general idea was: to establish a relation between some

parameters based on theoretical considerations; to use one parameter to predict the other one; and test the model with additional empirical observations. Clarke (1972, 3) writes that "Hypotheses are generated from the model expression of a theory. Explanation comes from tested hypotheses". A well-known use case of this approach is predictive modelling in archaeology (van Leusen et al. 2005).

This concept reduces models to some pure theoretical construct. This is still a valid concept for a certain part of the archaeological community, although the idea of distinguishing theoretical from empirical models (Mahr 2004) is more convincing and is currently spreading (Fig. 2; Nakoinz and Knitter 2016). Theoretical considerations can be used to construct a theoretical model. This can be compared with an empirical model based on empirical observations. When the empirical models fit the theoretical one, the theoretical considerations can be transferred (under certain conditions) to the empirical ones and new knowledge emerges.

Figure 2: Empirical Models, Theoretical Models and the Transfer of Information



Source: Nakoinz and Knitter 2016, fig. 2.5.

The work of Herbert Stachowiak on models was very influential in Germany and is also used in archaeology (Lemmen 2015). His definition, based on systems theory, is long and hence rarely cited. Stachowiak's characterization of models includes the three terms mapping, reduction and pragmatic, and is very comprehensive. We can translate this characterization into a definition: a model is a simplified mapping for a special purpose. This approach covers much more and also includes empirical models. An advantage is that this approach is not focused on prediction.

The meaning of the term model is usually not based on a coherent theory but on a common understanding in different discourses and contexts. There is a certain meaning of model, which can be connected, for instance, to model railways for children and diorama or ship models in museums. While this concept is covered by Stachowiak's approach, it does not agree with Clarke's

approach. 3D models of landscapes and archaeological documentation represents another, though related, understanding of the term model. Both types of model represent real world objects in order to show them as substitutes for the original. This approach can include the reconstruction of parts of objects.

The next category are models producing new information. Simulations are similar to empirical models, but they use artificial data produced according to the rules of theoretical models. Monte Carlo simulations and agent based models (Kohler and van der Leeuw 2007), for instance, are used in archaeology. For some archaeologists model is a synonym for simulation.

While simulations involve a random component, deterministic models produce definite results according to the applied rules. A frequent example in archaeology are Voronoi graphs, which produce exact borders between territories. Usually these lines are considered unrealistic and, without a comparison with an empirical model, this approach does not give much insight. With respect to concerning the real world representation of the model, conceptual modes are less strict. The social rank model for Iron Age Scandinavia (Fabech and Ringtved 1991), for example, distinguishes three social ranks which are connected to certain types of artefact. The model establishes certain ideas about the relationship between the members of these ranks. Conceptual models in general define the relationship between different entities and are also used in practical archaeology. Examples are the definition of workflows and the structure of organizations, as are database models. Conceptual models based on high level theories and concerned with the ancient world can be distinguished from those based on low level theories, which are concerned with the research process.

A rather important type of model, though they are rarely addressed as models, is the latent model (Nakoinz and Hinz 2015). Latent models represent the idea of certain relationships between entities, which tend to be implicit in many approaches and is rarely expressed explicitly. The typo-chronological model can serve as an example. The idea that artefacts of the same type are from the same period and similar types are from a similar period is the main assumption of the typo-chronological concept. This is nothing but a regression model formulated as a conceptual model, which has been used as a hidden assumption for many chronological considerations during the last two centuries.

Although examples of predictive models, such as Voronoi graphs and simulations, have been given above, quantitative models shall be mentioned as a category in its own right. The main idea of quantitative models is to establish or apply the relationship between different parameters using mathematical constructs. Frequently used methods are regression, interpolation, cluster analysis, correspondence analysis, and similar approaches. Classical interaction models mapping the intensity of interaction against the distance of interacting partners can serve as an example (Nakoinz 2013, 2014). Another well-known

example also imported from geography is the gravity model (Diachenko and Menotti 2012).

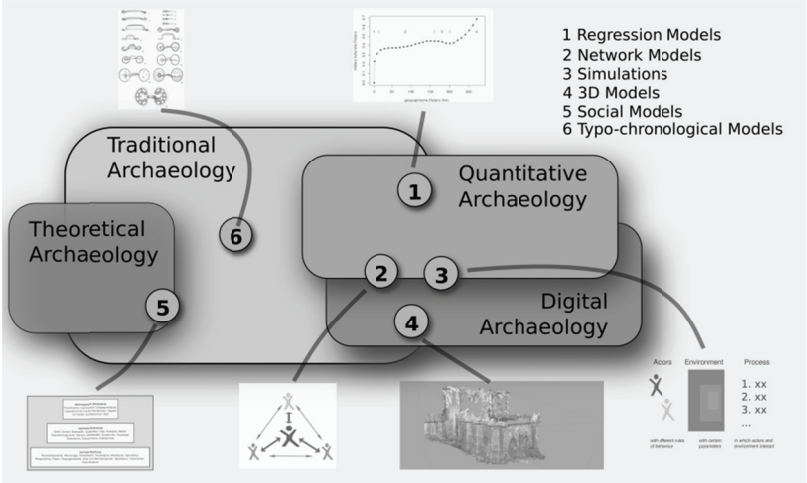
The term model is not used with the same intensity across all of these flavours of models. A laser scan of an archaeological site would be called a model, while traditional documentation, comprising drawings, photos, and descriptions, which in fact produce a kind of empirical model, is not considered a model. The frequency of the use of the term model is much higher for predictive modelling and quantitative models than for conceptual models such as data models. Therefore, the frequency of the use of the term model reflects the history of research with a certain bias. The use of the term model starts, in archaeology, in the 1960s and reaches a peak in the 1970s, due to the success of New Archaeology. The nadir of occurrences of model appears in the 1980s and 1990s because of the postprocessual critique which made use of different types of models while consistently avoiding the term model. Since the end of the 1990s, the usage of the term model has been increasing.

Currently, different kinds of models are in use in archaeology. The main categories are: predictive models, representative models, simulations, conceptual models, quantitative, and latent models. The different classes of models in archaeology are connected to different terminologies, and some are not even referred to as models at all. Different communities use different types of models for different purposes, based on different assumptions and the adoption of different terminologies. A definition of model or even a theory of model is required, which considers the social component of modelling and addresses the hidden assumptions. This idea is not only emerging from archaeology. In Kiel, the computer scientist Bernd Thalheim established an interdisciplinary group of researchers interested in models. This group developed a bottom up approach to modelling theory which solves some of the problems mentioned above (Thalheim and Nissen 2015). A model is defined as an artefact representing a part of the world. There is an analogy between model and original. A model is used in a certain community of practice as a tool for a certain purpose. Each community of practice shares some assumptions around the models it adopts, methods for developing and using models, and ideas for validating them. The shift of focus from the methodology of modelling and representative objects toward a practice of modelling in a certain community certainly supports the formation of a general theory of models as well as a common terminology in archaeology.

This short survey of the field of archaeological models reveals a heterogeneous set of models connected to different sub-disciplines and fields of research. Figure 3 is an attempt to locate different concepts of models in a disciplinary set diagram. Social models are placed in the field of theoretical archaeology, while typo-chronological models belong to traditional archaeology. Network models and simulations belong to both quantitative archaeology and digital archaeology. Regression models are associated with quantitative

archaeology, while 3D models belong to digital archaeology. This distribution is due to the different foci of the very tightly related sub-disciplines of quantitative and digital archaeology.

Figure 3: Examples of Models in Different Sub-Disciplines of Archaeology



Although there is a certain degree of overlapping and double membership, the different sub-disciplines still have their own communities. In particular, there are very few people who would claim to belong to the theoretical archaeological community as well as to the quantitative archaeology community. The reason for this separation of communities is of course the polarization of presumed paradigms.

3. Reasons for Using Models in Archaeology

The advantages of using models are obvious and as heterogeneous as the types of models themselves. Models and modelling are important not as objects, nor as methods, but as conceptual frameworks for handling knowledge, covering theory as well as practice. Models provide a structure for using and communicating comprehensive knowledge, inside and between disciplines. They provide a certain degree of abstraction, which makes it easier to establish connections between different theories, methods, and applications. In particular, models make it much easier to bridge the gap between science and the humanities, because they strip off the knowledge which is important for the different communities but which is not necessary for dealing with a certain topic. Since archaeology is a discipline in-between science and the humanities, this bridging

function is particularly promising for the advancement of the discipline. Models stimulate the creative process and give fast access to a certain topic? Models allow archaeologists to play with different points of view and to combine different ideas with nested models.

4. Conclusion

4.1 Which Term for Model?

Does it make sense to ask for a general definition for models, which covers all disciplines? The case of archaeology with various models borrowed from different disciplines shows the difficulties of developing a general definition of models. In addition, reducing the heterogeneity and using a specific term for models would minimise the integrative power of the model approach. A general term for models would, however, establish a basis for common understanding and communication. On the other hand, a very general definition, covering all possible types of models, would lack the precision required for many modelling tasks.

It is possible to benefit from both, the lack of an overarching terminology and the specificity of modelling practices at the same time. This requires a very open and general terminology for models to be subdivided into specific terms for different types of models. We already have a lot of specific terms for models, but we lack an accepted general terminology and in particular we lack a structure which establishes the connections between the different specific terms for models, a kind of family tree of models. In addition we lack the acceptance of specific terms for models used by diverse communities, since most communities assume that they are in possession of the right, most general and meaningful definition.

4.2 Four Levels of Using Models

In addition to problems with the definition of the term "model", we have to face the fact that there are some completely different ways of using models. We can define four levels of using models:

1. Models as Ontological Objects

The wax-model of a prehistoric man as it is exhibited in a museum and treated as an object representing another one might serve as an example. Constructing a model means producing an object which resembles something else and can be used to represent the original object. A model is used to communicate features of the original object by showing some similar features to its audience. The mapping or analogy is the key feature for this approach.

2. Models as Epistemological Model-Objects

The shift towards an epistemological perspective allows us to focus on the process of deriving new knowledge from models. Constructing a model is to produce something which has certain properties. The models are mainly used for comparison and hence the reduction of the original information to a set of important elements is the key feature of models in this approach.

The reconstruction of prehistoric houses from one area can be compared with those from another area. Digital elevation models are used to understand the ancient topography of an archaeological site. Regression models are used to establish dependencies of parameters of the location of settlements.

3. Modelling as a Practice of Solving Problems

The shift to a practical perspective characterises this use of models. Constructing a model means taking something and using this construct as a model for a certain task. Anything can be used as a model, but it is required that certain activities, when using the model, allow the modeller to complete a certain task. The model can be used as a replacement for the original in order to explore internal mechanisms and external relationships. Models as tools or instruments which can be used for a certain purpose is the key feature of models for this approach.

Simulations of social or environmental processes help us to understand the nature and possible outcome of these processes. Which parameters are leading to which types of settlement patterns? Which activities are required to grow certain crops? Is a population of x individuals for a settlement a reasonable assumption?

4. Modelling is a Research Framework

Finally, the shift of focus towards the communities of practice using certain models facilitates the formation of a research framework. Which assumptions are made by the relevant community of practice? How do they construct and use models? What exactly do the terms used in this community mean and how do they differ from similar terms in other communities? How are the models understood inside and outside the original community of practice?

Comparing the empirical models of archaeological evidence with the theoretical model of building structures such as houses or graves allows archaeologists to interpret the original data. This is usually done in archaeology without a reference to models. The modelling approach offers a clear and concise terminology and even a workflow which enables researchers to involve colleagues from other disciplines and other regions without extensive training in the specific terminology in use.

All four levels of the use of models make sense for specific purposes and we should not assume that one level is better than others. It seems to be much more

useful to find the right level for a certain objective. For instance, it does not make any sense to force all research into the "modelling as research framework" approach. This is certainly a concept from which many research projects can benefit, but for some research projects working in a well-established and efficient research environment without any need to communicate with other communities might reduce productivity and efficiency.

5. Perspectives

As long as "This is just a model!" is heard in archaeology, we are far away from a proper understanding of models and even further away from a fruitful adoption of models on a broad scale. Currently a rather small community in archaeology is working with different kinds of models and so contributing to modelling in archaeology.

In order to maximise the benefits of the modelling approaches in general and in archaeology, we need to complete some organizational, communicative and educational tasks:

1) Establishing a transdisciplinary modelling community. This community would ensure that knowledge transfer between communities is made possible. In particular, for archaeology, the exchange with other disciplines is essential. The present HSR Supplement as well as some other activities in recent years show that the development of this community is a work in progress.
2) Discussing a general terminology for models. Actually, it is not necessary to come up with a proper and universally accepted definition. Although it would be nice to have the perfect definition, the discussion itself develops transdisciplinary communication skills.
3) Connecting the different communities of practice to this transdisciplinary community. A small transdisciplinary modelling community without contacts to the disciplinary communities does not improve the scientific system as a whole. Since not all researchers can be involved in the transdisciplinary exchange, the communication between disciplinary modelling experts and transdisciplinary modelling experts is essential, in particular for the concept of modelling as a research framework.
4) Developing trans-disciplinary and disciplinary educational frameworks. The process towards modelling as a tool for trans-disciplinary communication and as a research framework starts with individuals, but needs to be based on the whole community. While the students of some disciplines receive a rather good education in modelling, an education on a trans-disciplinary level and in specific disciplines (such as archaeology) in still lacking. The basics of modelling must be part of the curriculum for archaeologists. This does not mean we must educate all archaeolo-

gists as modellers but it does mean we must ensure that everybody can communicate with modelling experts.

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